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Spatiotemporal patterns of distribution of large predatory sharks in Calabria (central Mediterranean, southern Italy)

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*During the 2000-2009, a survey study on the spatiotemporal patterns of distribution of large predatory sharks was carried out in the Calabria region. A total of 12 species were recorded and among them the blue shark *Prionace glauca* and the bluntnose sixgill shark *Hexanchus griseus* were the most common ones. Also of interest was the frequency of species such as *Carcharodon carcharias*, *Sphyrna zygaena* and *Cetorhinus maximus*. 57% of all reported records derived from the Tyrrhenian side of the region and 43% on the Ionian side. A significant relationship between season of the year versus number of records was found, but this could be related to the small number of observers that were active during the winter months. The presence of *Sphyrna lewini* is reported for the study area; this species was previously recorded only in the western part of the Mediterranean Sea. This paper also provides evidence of the second and first documented accounts of white shark predation upon *Tursiops truncatus* and *Stenella coeruleoalba*, respectively, in the Mediterranean Sea. The recovering of Ionian *Sphyrna zygaena* populations and the declining of *Lamna nasus* populations were also noted.*

Key words: Ecology, biogeography, elasmobranchs, *Sphyrna lewini*, *Carcharodon carcharias*, dolphins

INTRODUCTION

Usually at the apex of trophic chains, large predatory sharks play an important role in the structure and functioning of marine ecosystems (STEVENS *et al.*, 2000). Despite their evolutionary and ecological success, many species are increasingly threatened with extinction as a

result of human activities and the conservative life history traits of this group of fish. In fact, sharks are slow growing and late to mature, with low fecundity (COMPAGNO *et al.*, 2005). These characteristics result in a very low rate of potential population increase with little capacity to recover from overfishing and other threats such as pollution and habitat destruction (FOWLER *et*

al., 2005; VALENZUELA *et al.*, 2008). Many papers demonstrated that the decline of great sharks from coastal ecosystems have caused trophic cascades with marked ecological consequences (BAUM & MYERS, 2004; BASCOMPTE *et al.*, 2005; SHEPHERD & MYERS, 2005; MYERS *et al.*, 2007), as has been demonstrated for all apex predators,

both terrestrial and marine (ESTES *et al.*, 2011).

Although the Mediterranean is a semi-enclosed sea, the shark fauna is relatively diverse with an estimated 47 species of shark from 17 families (COMPAGNO, 2001; COMPAGNO *et al.*, 2005; SERENA, 2005) plus 4 alien species (ZENETOS *et al.*, 2010). However, currently, there is a lack of knowledge on their distribution.

Table 1. Large predatory sharks occurring in the Mediterranean Sea

Family	Species	Common name	Maximum length (cm)	Trophic level
Hexanchidae (cow sharks)	<i>Hexanchus griseus</i> (Bonaterre, 1788)	Bluntnose sixgill shark	480	4.3
Chinorehinidae (bramble sharks)	<i>Echinorhinus brucus</i> (Bonaterre, 1788)	Bramble shark	300	4.4
Odontaspidae (sand tiger sharks)	<i>Carcharias taurus</i> (Rafinesque, 1810)	Sand tiger	320	4.4
	<i>Odontaspis ferox</i> (Risso, 1810)	Smalltooth sand tiger	410	4.2
Alopiidae (thresher sharks)	<i>Alopias superciliosus</i> (Lowe, 1839)	Bigeye thresher	461	4.2
	<i>Alopias vulpinus</i> (Bonnaterre, 1788)	Thresher shark	600	4.2
Lamnidae (mackerel sharks)	<i>Isurus oxyrinchus</i> (Rafinesque, 1810)	Shortfin mako	400	4.3
	<i>Lamna nasus</i> (Bonnaterre, 1788)	Porbeagle	417	4.2
	<i>Carcharodon carcharias</i> (Linnaeus, 1758)	White shark	720	4.5
Carcharhinidae (requiem sharks)	<i>Carcharhinus altimus</i> (Springer, 1950)	Bignose shark	280	4.3
	<i>Carcharhinus brachyurus</i> (Günther, 1870)	Bronze whaler	292	4.2
	<i>Carcharhinus brevipinna</i> (Müller & Henle, 1839)	Spinner shark	280	4.2
	<i>Carcharhinus falciformis</i> (Müller & Henle, 1839)	Silky shark	350	4.2
	<i>Carcharhinus limbatus</i> (Müller & Henle, 1839)	Blacktip shark	255	4.2
	<i>Carcharhinus obscurus</i> (Lesueur, 1818)	Dusky shark	420	4.2
	<i>Carcharhinus plumbeus</i> (Nardo, 1827)	Sandbar shark	300	4.1
	<i>Prionace glauca</i> (Linnaeus, 1758)	Blue shark	380	4.1
Sphyrnidae (hammerhead sharks)	<i>Sphyrna lewini</i> (Griffith & Smith, 1834)	Scalloped hammerhead	420	4.1
	<i>Sphyrna mokarran</i> (Rüppell, 1837)	Great hammerhead	600	4.3
	<i>Sphyrna zygaena</i> (Linnaeus, 1758)	Smooth hammerhead	400	4.2

Of the 47 autochthonous species 20 can be considered top predators (Table 1). Large sharks historically occurred in the entire Mediterranean Sea although in recent decades they seemed to be restricted to the eastern and southern part or to offshore pelagic waters though with very low numbers (MEGALOFONOU *et al.*, 2005a, b; PSOMADAKIS *et al.*, 2009). Available evidence indicates that large predatory sharks in the Mediterranean Sea are generally declining in abundance, diversity and range (FOWLER *et al.*, 2005; FERRETTI *et al.*, 2008).

Only 3 species seemed to be regularly observed: *Prionace glauca*, *Isurus oxyrinchus* and *Alopias vulpinus*; the remaining species

Balearic region, the northern Adriatic and the Tyrrhenian Sea (SIMS, 2003; SIMS *et al.*, 2003). A small population of the smalltooth sand tiger shark *Odontaspis ferox* seems to be resident in a particular area off Lebanon (FERGUSSON *et al.*, 2008).

The main objective of this study was to describe the spatiotemporal distribution of large predatory sharks in Calabria (southern Italy, central Mediterranean). Different sources of information were used to determine shark distribution in the study area, in particular opportunistic fishing surveys and an extensive bibliographic search of the scientific literature. Spatiotemporal distribution data in the study area

Table 2. Large predatory sharks confirmed for the Calabria region

Species	N of records	Preferential habitat*
<i>Hexanchus griseus</i> (Bonnaterre, 1788)	17	Be, Ba
<i>Prionace glauca</i> (Linnaeus, 1758)	17	P, O
<i>Carcharodon carcharias</i> (Linnaeus, 1758)	8	Be, C, O
<i>Sphyrna zygaena</i> (Linnaeus, 1758)	7	Be, C, O
<i>Cetorhinus maximus</i> (Gunnerus, 1765)	7	Be, C, O
<i>Alopias vulpinus</i> (Bonnaterre, 1788)	5	P, C, O
<i>Isurus oxyrinchus</i> (Rafinesque, 1810)	4	P, C, O
<i>Lamna nasus</i> (Bonnaterre, 1788)	2	P, C, O
<i>Odontaspis ferox</i> (Risso, 1810)	1	Be, Ba
<i>Carcharhinus brevipinna</i> (Müller and Henle, 1839)	1	Be, C
<i>Carcharhinus plumbeus</i> (Nardo, 1827)	1	Be, C
<i>Sphyrna lewini</i> (Griffith and Smith, 1834)	1	Be, C, O

* according to Musick *et al.*, (2004). Legend: Ba = Bathydal; Be = Benthopelagic; C = Coastal; O = Oceanic; P = Pelagic)

have been only occasionally observed (SIMS *et al.*, 2000; SOLDO & JARDAS, 2000; FOWLER *et al.*, 2005; MEGALOFONOU *et al.*, 2005a, b; FERGUSSON *et al.*, 2008; PSOMADAKIS *et al.*, 2009; FERRETTI *et al.*, 2008; ZENETOS *et al.*, 2010). In addition, within the Mediterranean Sea the presence of these sharks is not homogenous (SERENA, 2005) and some areas were identified as critical habitats for great sharks. For example, Tunisian waters provide a nursery area for the white shark *Carcharodon carcharias* (FERGUSSON, 1996; SAIDI *et al.*, 2005). Aggregations of basking shark *Cetorhinus maximus* have been observed in the northern

are reported for each species. Furthermore, some ecological, bio-geographical and conservationist considerations are made; reports of predation of white shark versus cetaceans in the study area are also provided.

MATERIAL AND METHODS

Study area

Calabria is at the very south of the Italian peninsula. The region is a long and narrow peninsula, which stretches 248 km in the North/

South direction, with a maximum width of 110 km. It lies in the centre of the Mediterranean Sea (Fig. 1), between the Tyrrhenian and the Ionian Seas, and it is separated from Sicily by the Strait of Messina. Calabria, together with Sicily and the Tunisian coast, divides the Mediterranean Sea into western and eastern parts. The Tyrrhenian side of Calabria lays in the western Mediterranean, while the Ionian side in the eastern Mediterranean.

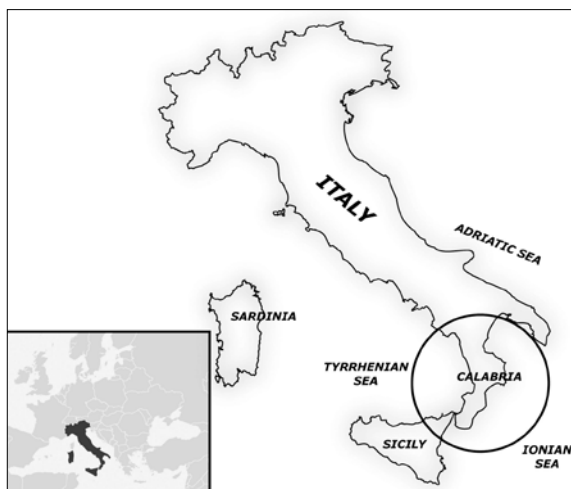


Fig. 1. Location map of the study area

Data collection

Records of large predatory sharks presented in this work come from nine years of opportunistic fishing surveys, from 2000 to 2009, and by various collaborations with fishermen, fisheries departments and marine police. In particular, commercial and recreational fisheries landings and sighting records were considered. Also a bibliographical search in the scientific literature and public and private archives was performed. According to FERRETTI *et al.* (2008), large predatory sharks were defined as species with a maximum length > 2 m and estimated trophic level > 4 (*in sensu* CORTÉS, 1999). In this study we also included data about the presence of *Cetorhinus maximus*, the world's second-largest fish, although it is not properly a predatory shark because it feeds on zooplankton. Shark identification and all common names used in this paper followed FAO nomenclature (COMPAGNO

et al., 2005; SERENA, 2005). All data that directly or indirectly provided information about the presence of these sharks in the study area were considered. Particularly, we divided our records into the following categories:

- sightings, when sharks were directly observed in the wild
- captures, referred to sharks caught onboard fishing vessels or observed in fishmonger's
- strandings, referred to dead sharks founded inshore or on the seashore
- indirect observations, such as feeding remains.

RESULTS

Of 20 species of large predatory shark that occur in the Mediterranean basin (DE METRIO *et al.*, 1984; MEGALOFONOU *et al.*, 2005a, b; FERRETTI *et al.*, 2008; PSOMADAKIS *et al.*, 2009) we confirmed for the study area the presence of 11 species, plus the presence of *Cetorhinus maximus*. In Table 1 the checklist of our 70 records is reported. 68.58% of the records referred to sharks caught onboard fishing vessels or observed in fishmongers', 22.85% of sharks were directly observed in the wild, 5.72% were dead sharks found inshore or on seashore and 2.85% were indirect observations. In Figure 2 are reported the typologies of records for each species of large predatory shark for the Calabrian region. The blue shark *Prionace glauca* and the bluntnose sixgill shark *Hexanchus griseus* were the most common species observed in the study area, while *Carcharodon carcharias*, *Sphyrna zygaena*, *Cetorhinus maximus*, *Alopias vulpinus* and *Isurus oxyrinchus* were the next

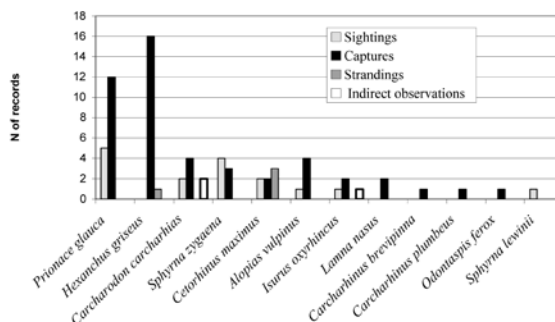


Fig. 2. Typologies of records of large predatory sharks reported for the study area

most abundant ones. The remaining five species (*Lamna nasus*, *Carharhinus brevipinna*, *Carcharhinus plumbeus*, *Odontaspis ferox* and *Sphyrna lewini*) were reported only once or twice. Looking at the spatial distribution of sharks, 57% of records occurred along the Tyrrhenian side of the Calabrian region, while 43% were on the Ionian side. The spatial distribution of the records is shown in Figure 3. Only three species (*Prionace glauca*, *Hexanchus griseus*, *Cetorhinus maximus*) are homogeneously distributed on both sides. *Carcharodon carcharias* and *Isurus oxyrinchus* were most often observed along the Tyrrhenian side, while *Sphyrna zygaena* and *Alopias vulpinus* were most often observed along the Ionian side. However, if we look at the distribution of the other five species, *Carcharhinus plumbeus* was found only in the Ionian side of Calabria, while *Carcharhinus brevipinna*, *Lamna nasus*, *Odontaspis ferox*

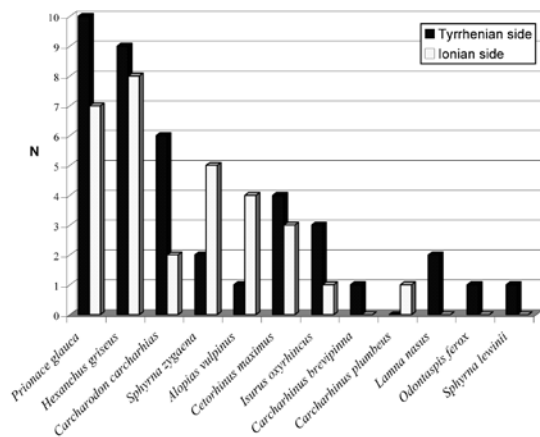


Fig. 3. Distribution of records along Tyrrhenian and Ionian sides of the study area

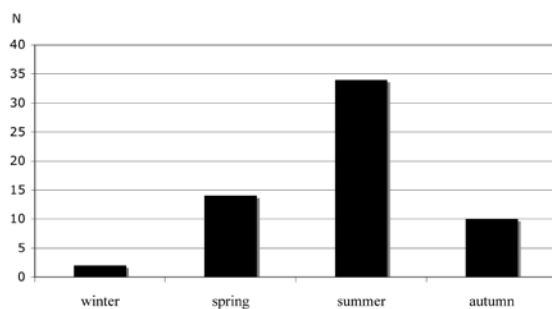


Fig. 4. Distribution of records among seasons for a calendar year

and *Sphyrna lewini* were found only in the Tyrrhenian side of the region. We also correlated the number of records versus the seasons of the year; although a high number of records (56.6%) has been reported for the summer season (Figure 4) with a significant relationship between these two variables ($\chi^2=18.343$; d.f.=3; $P=0.0004$), this could be related more to the small number of observers that were active during the winter months rather than to an effective temporal absence of sharks.

Interesting information come from the shark-bitten carcasses of two odontocetes (Figure 5). The first record was a bottlenose dolphin *Tursiops truncatus* found in Soverato (Ionian side of Calabria) on 03 July 2008. Bites were

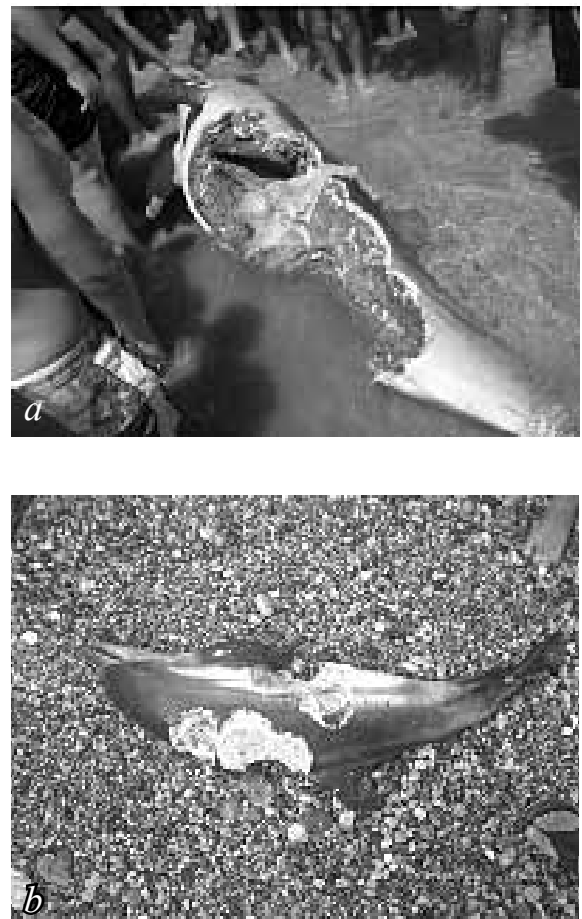


Fig. 5. White shark bites on cetaceans in the study area: bottlenose dolphin *Tursiops truncatus* found in Soverato on 03 July 2008 (a); striped dolphin *Stenella coeruleoalba* found in Melito di Porto Salvo on 16 August 2009 (b)

located in the urogenital region and on the abdomen. The second record was a striped dolphin *Stenella coeruleoalba* found in Melito di Porto Salvo (Ionian side of the region) on 16 August 2009. In this case, bites were located on the dorsum and on the abdomen. Following methods on the dental morphology of bites (LONG & JONES, 1996) led to identification of white shark *Carcharodon carcharias*.

DISCUSSION

The 12 species of shark confirmed for the Calabrian region represent 57,14% of the species of large predatory sharks reported for the Mediterranean Sea (COMPAGNO, 2001; COMPAGNO *et al.*, 2005; SERENA, 2005). This shark biodiversity could be correlated to the overall faunistic richness and diversity of marine coastal habitats present in the study area. Among the reported species, *Prionace glauca* and *Hexanchus griseus* were the most common. The dominance of *Prionace glauca* is consistent with other studies (DE METRIO *et al.*, 1984; MEGALOFONO *et al.*, 2005a, b; PSOMADAKIS *et al.*, 2009). However, comparison of historical data from swordfish fisheries with a more recent study has revealed that the catch rates in the central Mediterranean Sea over the last 20 years have decreased by an average of 38.5% (DE METRIO *et al.*, 1984; MEGALOFONO *et al.*, 2005b). *Hexanchus griseus* is also a common species in the Mediterranean; in particular, it is more common in the western basin, while it is less common in the eastern basin (COMPAGNO *et al.*, 2005; MEGALOFONO *et al.*, 2005a; SERENA, 2005). In Calabria, this species showed a homogeneous distribution on both the Tyrrhenian and Ionian sides of the region.

Records of the white shark *Carcharodon carcharias* in Calabria were more frequent along the Tyrrhenian side than the Ionian side. Our data confirm the general distribution described for this species in the Mediterranean Sea. In fact, it is known that white sharks were observed from all national coasts of the western Mediterranean basin, while infrequent records are known for the eastern basin (FERGUSON, 1996). Recently KABASAKAL & ÖZGÜR GEDIKOGLU (2008)

reported the capture of two newborns of white shark from Turkish waters of the north Aegean Sea. Further information about the feeding ecology of this species in the Mediterranean Sea comes from the records of the two dolphins bitten by white sharks along the Ionian side of the Calabria region. It is known that the white shark is a versatile predator and scavenges upon a wide spectrum of prey. Stomach content data demonstrated that this shark is piscivorous at all size classes despite a shift with maturity towards larger prey including marine mammals, principally pinnipeds (FERGUSON *et al.*, 2000; ESTRADA *et al.*, 2003; MARTIN *et al.*, 2005; ESTRADA *et al.*, 2006; SPERONE *et al.*, 2010). In the Mediterranean Sea pinnipeds are scarce or essentially absent and white sharks feed upon odontocetes or large pelagic fish, and sporadically upon chelonians (FERGUSON, 1996; FERGUSON *et al.*, 2000). Our data represent the second documented account of white shark predation (or possible scavenging) upon *Tursiops truncatus* and the first documented account of *Stenella coeruleoalba* for the Mediterranean Sea. The morphology and position of the bites on the body of the two dolphins follow the patterns described by LONG & JONES (1996). Data about predator-prey interactions between white sharks and *Stenella coeruleoalba* were not available for the study area, while only one confirmed record about predation upon *Tursiops truncatus* has been reported (FERGUSON, 1996).

Sphyrna zygaena was the next most abundant species in the study area. This species was more frequent along the Ionian side of the Calabria region and this reflects the general trend described by FERRETTI *et al.* (2008) for the Mediterranean Sea. Populations of this shark had the fastest decline among the investigated species by various authors. In particular, they started to decline in the Tyrrhenian Sea in the early 20th Century. From 1995 FERRETTI *et al.* (2008) found no more records of hammerhead sharks in Ionian investigated longlines. Our data demonstrate a recovery for the populations of this shark on the Ionian side of Calabria. All our records refer to sharks observed or captured in coastal areas such as the specimen shown

in Figure 6 and observed inshore in Soverato (Ionian side of Calabria) on 07 September 2008. A newborn of the species was also observed at the same location.

Basking shark *Cetorhinus maximus* showed a homogeneous distribution along the coasts of the entire Calabria region. The number of records

part. However, drastic declines were detected and documented by FERRETTI *et al.* (2008) in the Ionian Sea mainly due to recreational catches.

Records of other lamnoid shark species (*Isurus oxyrinchus* and *Lamna nasus*) showed a higher frequency along the Tyrrhenian side of Calabria, as observed for the white shark.



Fig. 6. Hammerhead shark *Sphyrna zygaena* observed inshore in Soverato on 07 September 2008

support the opinion that it is a relatively rare but constant species, as also reported for other areas (SIMS *et al.*, 2000; SOLDI & JARDAS, 2000). The highest occurrence of the basking shark has been observed from spring until autumn. This could be related to zooplankton abundance in this time period (SIMS & QUALE, 1998).

Records of *Alopias vulpinus* were distributed over the entire Calabria region, with the highest occurrence along the Ionian side. This pattern is in accordance with other reports (MEGALOFONO *et al.*, 2005a, b) in which a higher number of records of the species was observed more for the eastern Mediterranean than for the western

Compared to other reports for the Mediterranean Sea, the number of Calabrian records is definitely lower than the number of records for other Mediterranean areas (SOLDI & JARDAS, 2000; MEGALOFONO *et al.*, 2005a, b). FERRETTI *et al.* (2008) affirmed that Lamnids had the second-largest declines after hammerhead sharks. In particular, *Lamna nasus* showed the most serious depletion. A strong reduction in abundance and geographical distribution in this species has been observed, and its actual presence in the Mediterranean Sea appears to be restricted to the central basin (STEVENS *et al.*, 2000).

The other four species were reported

only once in Calabria. *Odontaspis ferox* was confirmed for the central-western Mediterranean and it is reported as occasionally caught in Italian waters of the Calabrian Tyrrhenian Sea (FERGUSON *et al.*, 2008). Occurrences eastwards of the Ionian Sea were never reported. Our record along the Tyrrhenian side of Calabria and the absence of records along the Ionian side seems to confirm this. The few records of requiem sharks (*Carcharhinus brevipinna* and *Carcharhinus plumbeus*) could be explained, according to RELINI *et al.* (2000) and FERRETTI *et al.* (2008) as a consequence of a rapid decline of these sharks. Requiem sharks are predators inhabiting coastal environments, and sharks that prefer these habitats may have declined more precipitously and earlier. Finally, of particular biogeographical value is the record of *Sphyrna lewini*. In fact this species was known only for the western Mediterranean Sea, from Gibraltar to the Balearic Islands (COMPAGNO *et al.*, 2005; SERENA, 2005). The specimen we observed in San Lucido (Tyrrhenian side of Calabria) on 15 July 2008 is not only the first record of this species for Italian waters, but also the easternmost record for the species in the entire Mediterranean (SERENA, 2005).

The absence of the species *Carcharias taurus*, *Carcharhinus limbatus*, *Carcharhinus obscurus* and *Sphyrna mokarran* in the study area is a consequence of their occasional presence in the entire Mediterranean Sea (BOERO & CARLI, 1977; COMPAGNO *et al.*, 2005; SERENA, 2005). The species *Alopias superciliosus*, *Carcharhinus altimus*, *Carcharhinus brachyurus*, *Carcharhinus falciformis* and *Echinorhinus brucus* have been previously reported for the western Mediterranean (MORENO & HOYOS, 1983; VACCHI *et al.*, 1996; ORSI RELINI, 1998; GOLANI *et al.*, 2002; SERENA, 2005; ZENETOS *et al.*, 2010) and for this reason they were not observed in the study area.

CONCLUSIONS

Our study provides a reference point for the knowledge and assessment of the status of large predatory pelagic sharks in the central Mediterranean Sea. Until now there has been

little documentation about the presence of these fish in this area. Due to the lack of existing data, no further speculation could be made. However, these data could represent a starting point for planning conservation measures. Particularly remarkable is on one hand the probable recovering of Ionian *Sphyrna zygaena* populations and, on the other hand, the declining of Tyrrhenian *Lamna nasus* populations. Long-term monitoring programs should be established in order to acquire further and more useful information for the realization of conservation plans for these sharks in an area (the Calabrian region) that represents an exchange channel between the western and eastern Mediterranean Sea.

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Prostorno vremenski modeli raspodjele velikih morskih pasa u Kalabriji (srednji Mediteran, južna Italija)

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SAŽETAK

U razdoblju od 2000 do 2009, provedeno je istraživanje prostorno-vremenskih obrazaca raspodjele velikih grabežljivih morskih pasa u talijanskoj regiji Calabria. Ukupno je zabilježeno 12 vrsta, te su među njima najčešće bili zastupljeni morski pas modrulj *Prionace glauca* i glavonja *Hexanchus griseus*. Zanimljiva je i učestalost vrsta kao što su velika bijela psina *Carcharodon carcharias*, mlat *Sphyrna zygaena* i psina golema *Cetorhinus maximus*. Od svih prijavljenih nalaza 57% je ostvareno na Tirenskoj strani regije, a 43% na Jonskoj strani. Ustanovljena je značajna povezanost između godišnjih doba u odnosu na broj zapisa, ali to bi moglo bi se moglo odnositi na mali broj promatrača koji su bili aktivni tijekom zimskih mjeseci. Prisutnost *Sphyrna lewini* je ustanovljena na istraživanom području: ova vrsta je prethodno bila zabilježena samo u zapadnom dijelu Sredozemnog mora. U radu se također navodi prvi i drugi dokumentirani nalaz bijelog morskog psa kao grabežljivca vrste dobrog dupina *Tursiops truncatus* i plavobijelog dupina *Stenella coeruleoalba* u Sredozemnom moru. Također je primjećen oporavak jonske populacije mlata *Sphyrna zygaena* i pad populacije kučine *Lamna nasus*.

Ključne riječi: ekologija, bio-geografija, elasmobranhije, mlat *Sphyrna lewini*, velika bijela psina *Carcharodon carcharias*, dupini